U.S. Department of the Interior
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METHODS FOR ESTIMATING TRIBUTARY STREAMFLOW IN THE CHATTAHOOCHEE RIVER BASIN BETWEEN BUFORD DAM AND FRANKLIN, GEORGIA

Open-File Report 98-63

Prepared in cooperation with the
Georgia Department Of Natural Resources
Environmental Protection Division

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By Timothy C. Stamey

U.S. GEOLOGICAL SURVEY

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GEORGIA DEPARTMENT OF NATURAL RESOURCES
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VERTICAL DATUM

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly call Sea Level Datum of 1929.

Altitude: as used in this report, refers to distance above or below sea level.

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ABSTRACT

Simple and reliable methods for estimating hourly streamflow are needed for the calibration and verification of a Chattahoochee River basin model between Buford Dam and Franklin, Ga. The river basin model is being developed by Georgia Department of Natural Resources, Environmental Protection Division, as part of their Chattahoochee River Modeling Project. Concurrent streamflow data collected at 19 continuous-record, and 31 partial-record streamflow stations, were used in ordinary least-squares linear regression analyses to define estimating equations, and in verifying drainage-area prorations. The resulting regression or drainage-area ratio estimating equations were used to compute hourly streamflow at the partial-record stations. The coefficients of determination (r-squared values) for the regression estimating equations ranged from 0.90 to 0.99.

Observed and estimated hourly and daily streamflow data were computed for May 1, 1995, through October 31, 1995. Comparisons of observed and estimated daily streamflow data for 12 continuous-record tributary stations, that had available streamflow data for all or part of the period from May 1, 1995, to October 31, 1995, indicate that the mean error of estimate for the daily streamflow was about 25 percent.

INTRODUCTION

Because of widespread and rapid development in the Chattahoochee River basin between Buford Dam, and Franklin, Ga., a better understanding of the hydrologic characteristics of the tributary streamflow is required to effectively manage the basin’s water resources. Historically, water-resource management decisions were made considering only hot or dry weather conditions. However, as a result of increased growth and development, wet-weather conditions and stormwater runoff also need to be considered to ensure adequate water supplies, water control, and water-quality allocations within the river basin. These management decisions are dependent on the use of a river basin model being developed by the Georgia Department of Natural Resources, Environmental Protection Division (EPD), which requires reliable hourly streamflow data.

This report is the result of a cooperative project between the U.S. Geological Survey (USGS) and the EPD. All streamflow data used in this study were collected by the USGS and EPD.

Purpose and Scope

This report describes:

- the hydrologic conditions in the Chattahoochee River basin from Buford Dam downstream to Franklin, Ga.;
- the methods used to develop equations for estimating hourly and computing daily streamflow at 47 Chattahoochee River tributaries; and
- the method used to transfer the observed and estimated streamflow from each gaged location to the mouth of each tributary.

Between April 1994 and December 1995, 13 continuous-recording and 31 partial-record streamflow stations were established in the study area between Buford Dam and Franklin, Ga. (fig. 1). The newly established streamflow stations were located on tributaries having drainage areas greater than 3 square miles (mi^2). Streamflow measurements are used in ordinary least-squares linear regression analyses to define estimating equations and to verify the use of basin-adjustment factors for the 47 selected tributaries in the study area. These estimating equations were developed and used to compute hourly and daily streamflow for the partial-record tributaries for the period May 1, 1995, through October 31, 1995. The streamflow-estimating equations are based on analyses of concurrent streamflow measurements or drainage-area ratios at 18 continuous-recording streamflow stations (data from one continuous-recording streamflow station were not available during May 1-October 31, 1995) and 32 partial-record streamflow stations (fig. 1, tables 1, 2).

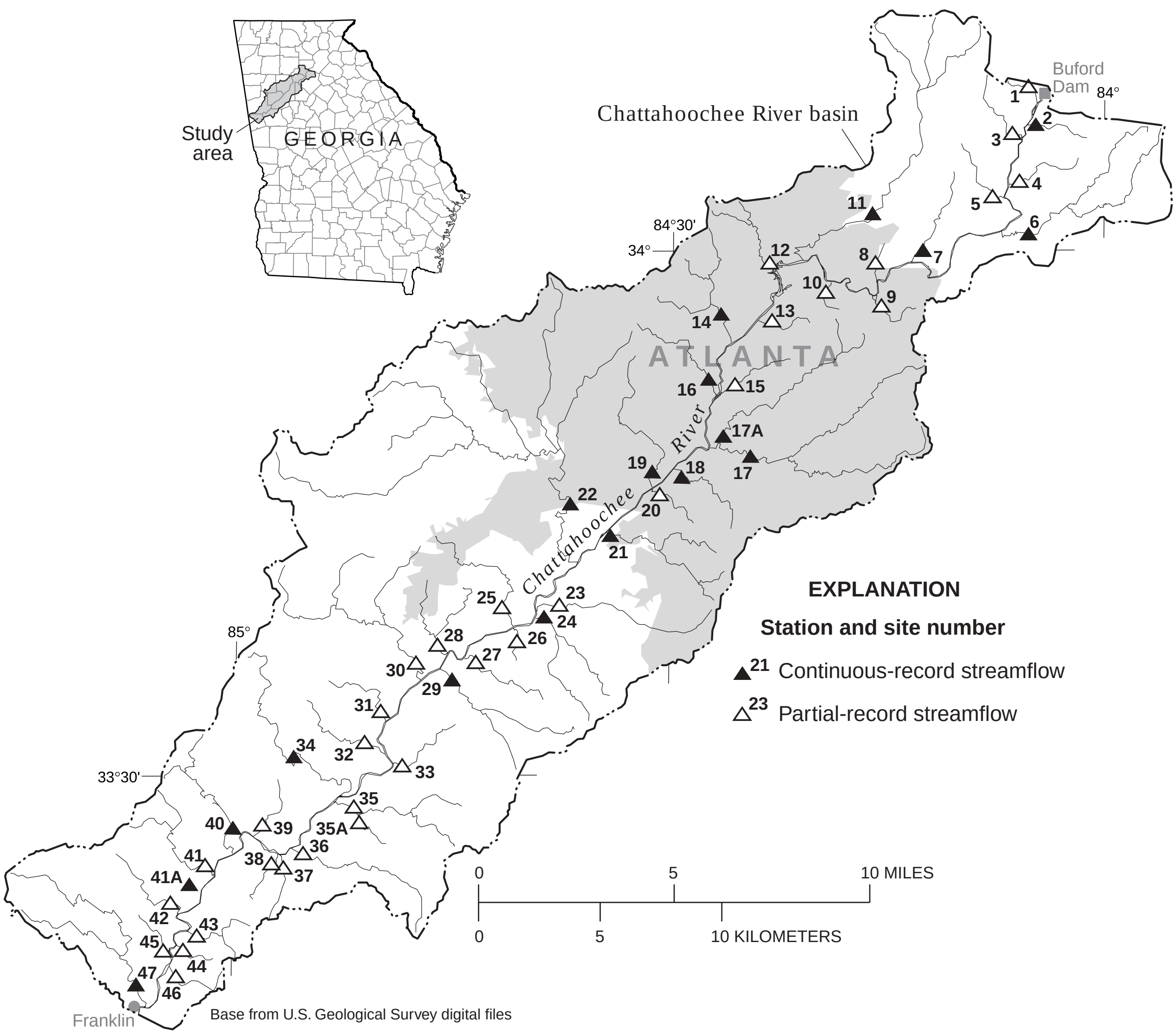

Figure 1. Study area and locations of continuous-record and partial-record streamflow stations.

[

Table 1. Drainage-area data for tributary watersheds, in downstream order
[NA, not applicable; NF, no flow in stream due to diversion; mi^2, square miles]

Site number (fig. 1)	Watershed name	Drainage area at data-collection location (mi^2)	Drainage area at mouth (mi^2)
1	Haw Creek	1.7	3.8
2	Richland Creek	8.8	10.6
3	James Creek	15.1	15.2
4	Level Creek	8.2	9.1
5	Dick Creek	7.1	8.8
6	Suwanee Creek	46.8	51.2
7	Johns Creek	11.6	13.1
8	Unnamed Creek	2.4	3.7
9	Crooked Creek	8.5	9.2
10	Ball Mill Creek	3.2	3.5
11	Big Creek	75.6	103
12	Willeo Creek	16.1	19.8
13	March Creek	4.8	5.3
14	Sope Creek	32.3	35.4
15	Long Island Creek	6.2	6.4
16	Rottenwood Creek	19.5	19.6
17	Peachtree Creek	86.8	131
17A	Nancy Creek (sub-watershed to Peachtree Creek)	37.0	38.0
18	Proctor Creek	15.9	16.4
19	Nickajack Creek	31.7	36.7
20	Sandy Creek	4.2	5.1
21	Utoy Creek	33.9	34.2
22	Sweetwater Creek	246	264
23	Camp Creek	45.1	46.8
24	Deep Creek	29.2	29.9
25	Anneewakee Creek	28.1	29.9
26	Tuggle Creek	3.1	3.2
27	Pea Creek	13.5	14.5
28	Bear Creek (Douglas County)	17.0	17.3
29	Bear Creek (Fulton County)	26.3	29.0
30	Dog River	78.4	78.5
31	Hurricane Creek	5.6	10.1
32	Wolf Creek	16.7	16.8
33	White Oak Creek	16.1	16.6
34	Snake Creek	35.5	49.2
35	Cedar Creek	43.2	51.8
35A	Panther Creek (sub-watershed to Cedar Creek)	4.4	4.7
36	Wahoo Creek	33.3	34.6
37	Thomas Creek	8.0	8.9
38	Moore Creek	3.4	3.5
39	Acorn Creek	10.8	11.2
40	Whooping Creek	27.1	31.4
41	Yellowdirt Creek	NF	NF
41A	Plant Wansley outfall	NA	NA
42	Pink Creek	9.3	10.2
43	Hilly Mill Creek	11.0	12.4
44	Red Bone Creek	2.0	3.0
45	Nutt Creek	5.0	5.1
46	Harris Creek	6.1	7.4
47	Centralhatchee Creek	56.8	58.8

Table 2. Period of available data for continuous-record tributary streamflow stations in the study area

Site number (fig. 1)	Station number	Station name	Available data
2	02334480	Richland Creek near Buford	September 29, 1995 to December 31, 1996
6	02334885	Suwanee Creek near Suwanee[1/]	October 1, 1984 to September 30, 1997
7	02335078	Johns Creek near Warsaw	April 13, 1995 to September 30, 1997
11	02335700	Big Creek near Alpharetta[1/]	May 1, 1960 to September 30, 1997
14	02335870	Sope Creek near Marietta[1/]	October 1, 1984 to September 30, 1997
16	02335912	Rottenwood Creek at Atlanta	September 29, 1995 to September 30, 1996
17	02336300	Peachtree Creek at Atlanta[1/]	June 20, 1958 to September 30, 1997
17A	02336410	Nancy Creek at Atlanta.	August 22, 1994 to September 30, 1997
18	02336529	Proctor Creek near Atlanta	April 27, 1995 to September 30, 1997
19	02336635	Nickajack Creek near Mableton	October 2, 1995 to September 30, 1997
21	02336728	Utoy Creek near Atlanta	August 31, 1994 to September 30, 1996
22	02337000	Sweetwater Creek near Austell[1/]	March 24, 1937 to September 30, 1997
24	02337160	Deep Creek near Tell	October 2, 1995 to September 30, 1997
29	02337320	Bear Creek near Rico	April 28, 1995 to September 30, 1997
34	02337500	Snake Creek near Whitesburg[1/]	September 15, 1954 to September 30, 1997
36	02338185	Wahoo Creek near Sargent	December 4, 1995 to December 31, 1996
40	02338280	Whooping Creek near Whitesburg	August 31, 1994 to December 31, 1996
41A	[2/]02338314	Plant Wansley outfall near Glenloch	April 28, 1995 to December 31, 1996
47	02338400	Centralhatchee Creek near Franklin	August 31, 1994 to December 31, 1996

[1/]Station records available prior to April 1994.
[2/]Station is a permitted outfall for power plant and is not a free-flowing tributary.

Table 3. Tributary watershed analysis data used for May 1, 1995 to October 31, 1995

[—, not applicable; FC, Fulton County; NF, no flow in stream due to diversion]

Watershed		Index station	Regression equation				
Site number (fig. 1)	Name		Slope [1]	Intercept[1]	Drainage-area ratio	Coefficient of determination	Basin-adjustment factor
1	Haw Creek	Johns Creek	—	—	0.15	—	2.18
2	Richland Creek	Suwanee Creek[2]	0.14	2.7	—	0.95	1.20
3	James Creek	Johns Creek	—	—	1.30	—	1.00
4	Level Creek	Johns Creek	—	—	0.71	—	1.11
5	Dick Creek	Johns Creek	—	—	0.61	—	1.25
6	Suwanee Creek	Suwanee Creek	—	—	—	—	1.11
7	Johns Creek	Big Creek[2]	0.07	0.8	—	0.99	1.13
8	Unnamed Creek	Johns Creek	—	—	0.21	—	1.53
9	Crooked Creek	Sope Creek	0.34	-0.7	—	0.90	1.09
10	Ball Mill Creek	Sope Creek	—	—	0.10	—	1.09
11	Big Creek	Big Creek	—	—	—	—	1.36
12	Willeo Creek	Big Creek	0.22	-0.3	—	0.92	1.23
13	March Creek	Nancy Creek	—	—	0.13	—	1.09
14	Sope Creek	Sope Creek	—	—	—	—	1.10
15	Long Island Creek	Nancy Creek	—	—	0.17	—	1.03
16	Rottenwood Creek	Sope Creek[2]	0.54	1.0	—	0.92	1.01
17	Peachtree Creek	Peachtree Creek	—	—	—	—	[3]+ Nancy Creek x 1.10
17A	Nancy Creek	Peachtree Creek [2]	0.72	-6.0	—	0.91	—
18	Proctor Creek	Peachtree Creek [2]	—	—	0.18	—	1.03
19	Nickajack Creek	Sope Creek[2]	1.16	1.1	—	0.90	1.16
20	Sandy Creek	Peachtree Creek	0.05	-0.2	—	0.92	1.20
21	Utoy Creek	Peachtree Creek[2]	0.25	8.0	—	0.96	1.01
22	Sweetwater Creek	Sweetwater Creek	—	—	—	—	1.00
23	Camp Creek	Bear Creek (FC)	—	—	1.72	—	1.04
24	Deep Creek	Bear Creek (FC)[2]	—	—	1.11	—	1.02
25	Anneewakee Creek	Snake Creek	0.92	-1.9	—	0.93	1.06
26	Tuggle Creek	Bear Creek (FC)	—	—	0.12	—	1.02
27	Pea Creek	Bear Creek (FC)	—	—	0.51	—	1.07
28	Bear (Douglas)	Bear Creek (FC)	—	—	0.65	—	1.02
29	Bear Creek	Snake Creek[2]	0.79	-3.0	—	0.90	1.10
30	Dog River	Bear Creek (FC)	—	—	2.98	—	1.00
31	Hurricane Creek	Snake Creek	0.11	2.0	—	0.97	1.80
32	Wolf Creek	Snake Creek	0.44	-0.6	—	0.95	1.01
33	White Oak Creek	Bear Creek (FC)	—	—	0.61	—	1.03
34	Snake Creek	Snake Creek	—	—	—	—	1.32
35	Cedar Creek	Snake Creek	1.20	-10	—	0.90	[3]+ Panther Creek x1.05
35A	Panther Creek	Snake Creek	0.10	-0.5	—	0.94	—
36	Wahoo Creek	Snake Creek	0.80	-6.0	—	0.90	1.04
37	Thomas Creek	Whooping Creek	—	—	0.29	—	1.12
38	Moore Creek	Whooping Creek	—	—	0.13	—	1.01
39	Acorn Creek	Whooping Creek	—	—	0.40	—	1.04
40	Whooping Creek	Snake Creek[2]	0.62	0.4	—	0.94	1.16
41	Yellowdirt Creek	NF	NF	NF	—	—	NF
41A	Plant Wansley outfall	Snake Creek[2]	.14	8.6	—	0.90	1.00
42	Pink Creek	Snake Creek	0.26	-0.02	—	0.96	1.10
43	Hilly Mill Creek	Snake Creek	0.28	-2.2	—	0.90	1.13
44	Red Bone Creek	Snake Creek	0.09	-1.1	—	0.96	1.50
45	Nutt Creek	Snake Creek	0.15	-1.7	—	0.97	1.02
46	Harris Creek	Snake Creek	0.20	-1.8	—	0.98	1.20
47	Centralhatchee Creek	Snake Creek[2]	1.0	1.7	—	0.92	1.04

[1]See Appendix A for explanation.
[2]Streamflow stations used for estimates and comparisons of continuous-record and partial-record periods.
[3]Add subwatershed data and multiply by basin-adjustment factor.

Description of Chattahoochee River Basin Study Area

The Chattahoochee River basin study area encompasses about 1,640 square miles (mi^2) from Buford Dam at river mile 348.3 to Franklin, Ga., at river mile 232.2 (fig. 1), and coincides with EPD's Chattahoochee River Modeling Project (CRMP) area. The average channel slope for this 116.1-mile reach is about 2.5 feet/mile, with approximate altitudes of 912 feet (ft) above sea level downstream of Buford Dam and 624 ft at Franklin.

The study area is divided into 47 tributary watersheds, each equal to or larger than 3 mi^2 (fig. 1, table 1). These watersheds include two sub-watersheds and one permitted outfall, for a total of 50 tributary stations; and comprise about 1,410 mi^2, or about 86 percent of the study area. The remaining 230 mi^2 includes drainage of tributary watersheds of 3 mi^2 or less and mainstem sections of the Chattahoochee River.

METHODS OF ANALYSES FOR ESTIMATING TRIBUTARY STREAMFLOW

Simple and reliable methods for estimating hourly and computing daily tributary streamflow are needed by EPD for an input dataset for calibration of their river basin model. Methods used to analyze and estimate tributary streamflow data include ordinary linear least-squares regression analyses (SAS Institute, Inc., 1990), drainage-area ratio analyses from selected continuous- and partial-record stations, and USGS automated processing applications (U.S. Geological Survey, 1990). Continuous streamflow data were collected at only 6 tributary locations prior to 1994 (table 2). Additional continuous-record tributary streamflow data, to be used as correlation-index stations, were needed to accurately estimate streamflow data for the EPD river basin model. Therefore, 13 tributary continuous-record streamflow stations and 31 partial-record streamflow stations were installed and operated from April 1994 through December 1996. Streamflow data collected were used in developing the estimating equations at all tributary locations (tables 1, 2, and 3). Streamflow data were compiled and computed on a routine basis from stage-discharge ratings developed for each continuous-record station. Streamflow data were collected at the partial-record stations on a periodic basis.

Regression Analysis

Ordinary least-squares linear regression analyses (SAS Institute, Inc., 1990) were used to develop the estimating equations for 25 of 31 partial-record tributary streamflow stations. These estimating equations were developed from concurrent streamflow data collected at the continuous-record and partial-record stations during the 1994-96 data-collection period. The number of streamflow measurements available for use in the regression analyses averaged about 17 measurements per station, and ranged from a minimum of 6 to a maximum of 37 during the data-collection period (Appendix A). Streamflow data are placed in a SAS data set and are regressed against each other using standard regression procedures (SAS Institute, Inc., 1990). Comparisons were made with several different continuous-record and partial-record stations to determine the best correlated stations. Index stations with the best correlations used in determining the streamflow estimating equations, were generally within the closest proximity to partial-record stations. Occasionally, the estimating equations computed streamflow values that were less than zero for two partial-record stations. These less than zero streamflow values were converted to zero flow values. Coefficients of determination (r-squared values) for the computed regression estimating equations range from 0.90 to 0.99.

Log transformation of the data was attempted as part of the analyses, but produced extremely large estimates for high runoff events. The ordinary least-squares regression analyses provided the best overall estimating method. A more detailed description of the regression procedures, and examples, are included in Appendix A.

Drainage-Area Ratio Analysis

At the request of EPD, 4 of the 13 newly implemented streamflow stations were selected as index-correlation stations to develop drainage-area ratios (DAR) for use in estimating streamflow for 19 partial-record tributary stations (tables 2 and 3). These selections were based on watersheds having similar l and use and that were adjacent to or in close proximity to the partial-record stations. The DAR of each partial-record station was determined by dividing the drainage area for that station by the drainage area of the index station. The resulting DAR estimates were verified during low-flow conditions by concurrent streamflow data collected at these streamflow stations. A more detailed description of the DAR procedures, and examples, are included in Appendix A.

Both of the estimating methods, ordinary linear least-squares regression and drainage-area ratio, produced simple and reliable estimating equations that are easily applied in estimating streamflow at the partial-record stations. The estimated streamflows were compared to observed streamflow where available—results of these comparisons are discussed in the section of this report “Comparisons of Observed and Estimated Tributary Streamflow Data” and shown graphically in figures 2-13.

Basin-Adjustment Factor Analysis

A basin-adjustment factor (BAF) was determined at each of the 47 tributary streamflow stations to transfer the estimated and observed streamflow data to the tributary mouth. The BAFs are based on drainage-area prorations between the gaged location and the tributary mouth. The BAFs were verified at several tributaries by making concurrent streamflow measurements during low-flow periods, near the mouth and at the gaged location on the tributaries. The BAF was verified by converting the measured streamflow in cubic feet per second (ft^3/s) at the mouth and gage location to a cubic foot per square mile (ft^3/mi^2) value. This was accomplished by dividing the measured streamflows by the respective tributary drainage areas at the confluence with the Chattahoochee River and at the tributary gage location where concurrent streamflow data were collected. In all cases where concurrent streamflow data were available, the ft^3/mi^2 values for each tributary were nearly equal at the mouth and gage location; thus, verifying the use of the drainage-area proration values as the basis for determining BAFs. The resulting basin-adjustment factors are shown in table 3. A more detailed explanation, along with examples of the data-analysis procedures, are included in Appendix A.

Data-Processing Application

Estimates of hourly and daily streamflow were computed using the USGS Automated Data Processing System (ADAPS) for May 1 through October 31, 1995, from the corresponding continuous-record (index stations) and partial-record streamflow-data-collection stations, using the estimating equations and information from table 3. The tributary streamflow data were processed for the 50 tributary stations in the ADAPS data base and the estimated streamflow data were computed using standard USGS procedures (U.S. Geological Survey, 1990). The first part of the process included collection and compilation of stream-stage and discharge data at the continuous-record streamflow stations (index stations) and transferring that data to all of the associated tributary stations in the ADAPS data base. The equations then were input into ADAPS for each station as determined from regression analyses or drainage-basin ratios, as previously discussed. The ADAPS processing system then computes the hourly and daily streamflow data using the estimating equations and the observed streamflow data for each station.

Computed streamflows were compared to observed streamflows when concurrent data were available. In some cases, estimated streamflows were adjusted during data processing to better duplicate the concurrent observed streamflows by applying a streamflow correction based on the difference between the estimated and observed streamflow measurements made at specific dates and times. For example, if the estimated streamflow for October 1, 1995 at 1200 hours was 10 ft^3/s, and the observed or measured streamflow was 8 ft^3/s, a -2 ft^3/s correction would be applied to get the two values to match. The correction was always prorated from a previous observed date, time, and difference in streamflow to reflect the concurrent known streamflow, if available.

Once the estimates were computed, hourly and daily streamflow data were checked for processing errors and subjected to standard USGS quality-control procedures (U.S. Geological Survey, 1990). The finalized data were then output and converted to a tab-delimited format and made available for the CRMP model.

ACCURACY OF METHODS

The accuracy of the estimating equations derived from the data analyses depends on the accuracy and number of concurrent streamflow measurements, rainfall-distribution patterns, the stage-discharge relation stability at a continuous-record station, and most importantly, the degree of hydrologic similarity (correlation) between the index and partial-record stations. Normally, the lengths of record for the gaged locations also are important criteria for determining accuracy of streamflow characteristics. However, given certain time constraints and limited available tributary streamflow data, it was considered to be more important to collect an adequate number of streamflow measurements over a wide range of flow conditions at as many stations as possible. The accuracy of the estimated and observed streamflow data at 12 tributary continuous-record stations are compared in table 4 and are discussed in the following section.

Comparisons of Observed and Estimated Tributary Streamflow Data

Comparisons were performed on observed and estimated daily tributary streamflow data from 12 new continuous-record stations in operation from May 1, 1995 to October 31, 1995, to obtain a more practical evaluation of the statistical validity and an overall representation of the accuracy of the estimating equations (table 4). Hydrographs of daily concurrent observed and estimated streamflow data for these 12 stations are shown in figures 2-13. Comparison of daily streamflow data show the daily and period variations (May 1, 1995 to October 31, 1995) in selected streamflow characteristics and average-percent errors for the observed and estimated streamflow data (table 4). Even though estimating procedures are not as accurate as observed continuous data-collection methods, the results indicate that the estimating equations and methods used can provide a reliable estimating procedure, with a mean error of estimate for daily streamflow of about 25 percent (table 4, figs. 2-13). Estimates for the remaining 32 partial-record tributary stations that do not have continuous streamflow data are believed to have about the same mean-error of estimate.

The accuracy of estimating equations may be improved with additional streamflow measurements and data analysis—especially for periods of high streamflow. Most tributary stations could not be measured during high runoff periods; therefore, higher mean error of estimates resulted because of the lack of concurrent high streamflow measurements. The larger errors for the higher streamflow estimates were most pronounced in October 1995, because of significantly higher-than-normal streamflow resulting from Tropical Storm Opal. National Weather Service reports indicate about 8 to 10 inches of rain occurred in the study basin (National Weather Service, written comm., 1995). Most streamflow were measured during baseflow conditions; and therefore, resulted in lower error of estimates for the low or minimum streamflow conditions (table 4).

Table 4. Comparison of selected characteristics of observed and estimated daily streamflow for continuous-record tributary stations for the period May 1, 1995 to October 31, 1995

[ft^3/s, cubic feet per second]

Total daily streamflow			Maximum streamflow			Minimum streamflow		
Observed (ft^3/s)	Estimated (ft^3/s)	Error of estimate (percent)	Observed (ft^3/s)	Estimated (ft^3/s)	Error of estimate (percent)	Observed (ft^3/s)	Estimated (ft^3/s)	Error of estimate (percent)
02334480 Richland Creek near Buford, Ga.—site 2								
1,218	894.4	26.6	514	392	23.7	4.3	3.5	18.6
02335078 Johns Creek near Warsaw, Ga.—site 7								
3,056	1,504	50.8	759	138	81.8	1.1	1.5	36.4
02335912 Rottenwood Creek at Atlanta, Ga.—site 16								
3,280	1,862	43.2	1,530	748	51.1	8.0	8.1	1.2
02336410 Nancy Creek at Atlanta, Ga.—site 17A								
15,558	18,936	21.7	3,000	4,530	51.0	4.0	3.2	20.0
02336529 Proctor Creek near Atlanta, Ga.—site 18								
4,750	5,206	9.6	1,100	1,170	6.4	3.0	2.8	6.7
02336635 Nickajack Creek near Mableton, Ga.—site 19								
2,960	3,983	34.6	1,180	1,610	36.4	14.0	14.0	0
02336728 Utoy Creek near Atlanta, Ga.—site 21								
6,927	8,294	19.7	1,700	1,630	4.12	5.0	4.1	18.0
02337160 Deep Creek near Tell, Ga.—site 24								
2,550	2,790	9.4	1,000	1,190	19.0	9.0	7.9	12.2
02337320 Bear Creek near Rico, Ga.—site 29								
5,049	3,944	21.9	1,070	688	35.7	6.4	5.7	10.9
02338280 Whooping Creek near Whitesburg, Ga.—site 40								
3,773	3,231	14.4	1,070	543	49.2	4.5	4.6	2.2
02338314 Plant Wansley Outfall near Glenloch, Ga.—site 41A								
2,883	2,444	15.2	58	131	126	9.5	10.0	5.3
02338400 Centralhatchee Creek near Franklin, Ga.—site 47								
9,292	6,085	34.5	2,700	876	67.6	7.5	6.9	8.0
Mean errors of estimate								
		25.1			46.0			11.6

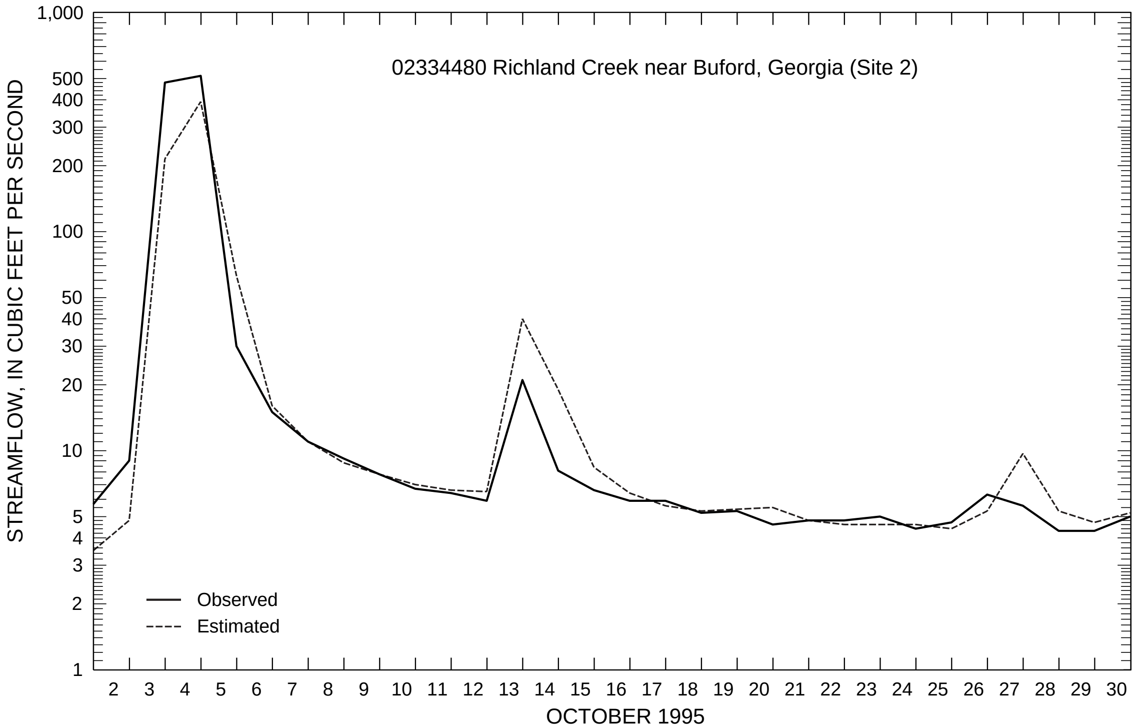

Figure 2. Comparison of observed and estimated daily tributary streamflow data for Richland Creek near Buford, Georgia.

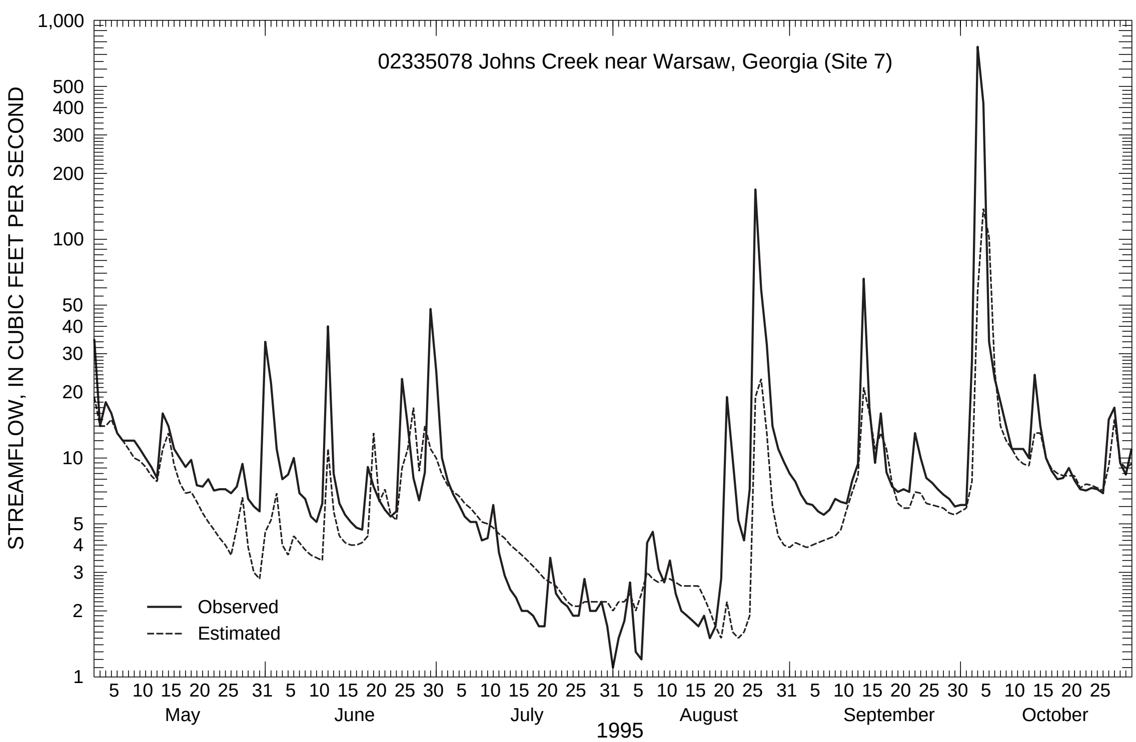

Figure 3. Comparison of observed and estimated daily tributary streamflow data for John Creek near Warsaw, Georgia.

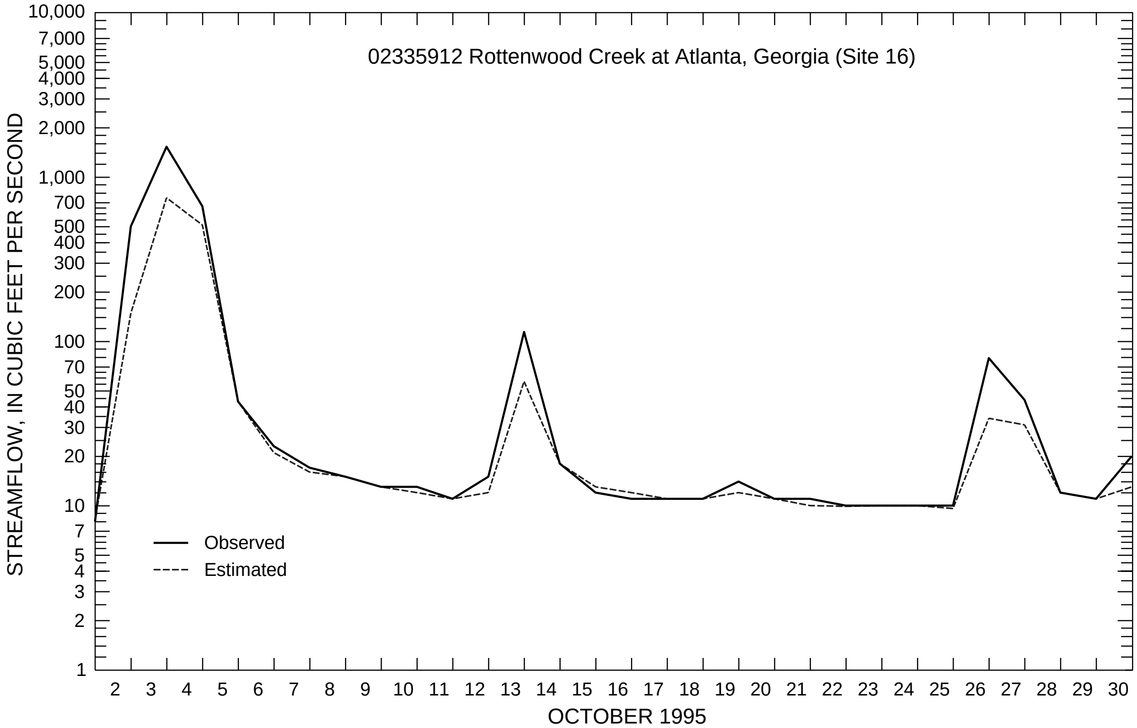

Figure 4. Comparison of observed and estimated daily tributary streamflow data for Rottenwood Creek near Atlanta, Georgia.

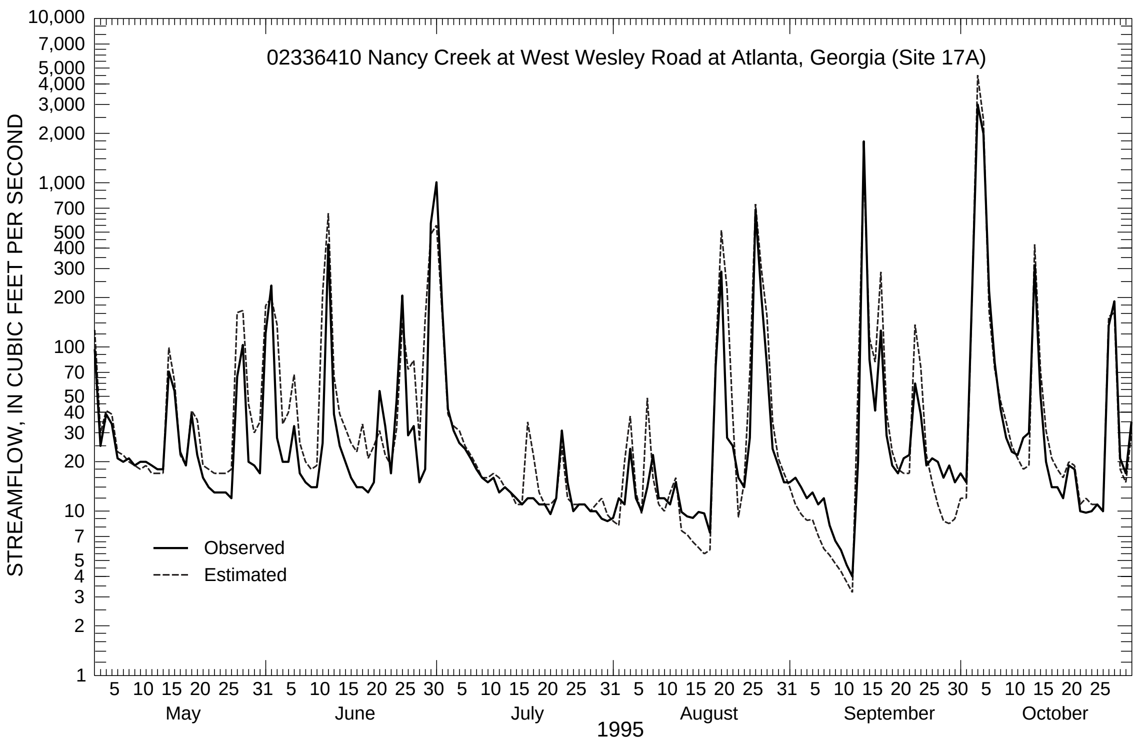

Figure 5. Comparison of observed and estimated daily tributary streamflow data for Nancy Creek at West Wesley Road at Atlanta, Georgia.

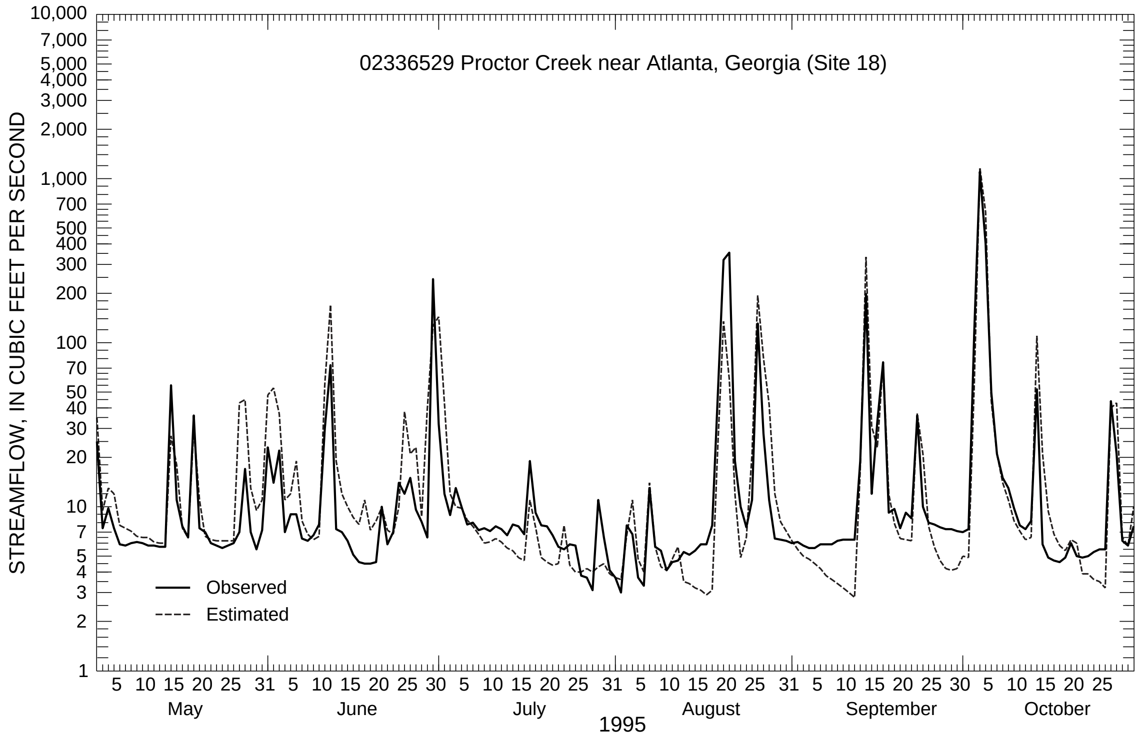

Figure 6. Comparison of observed and estimated daily tributary streamflow data for Proctor Creek near Atlanta, Georgia.

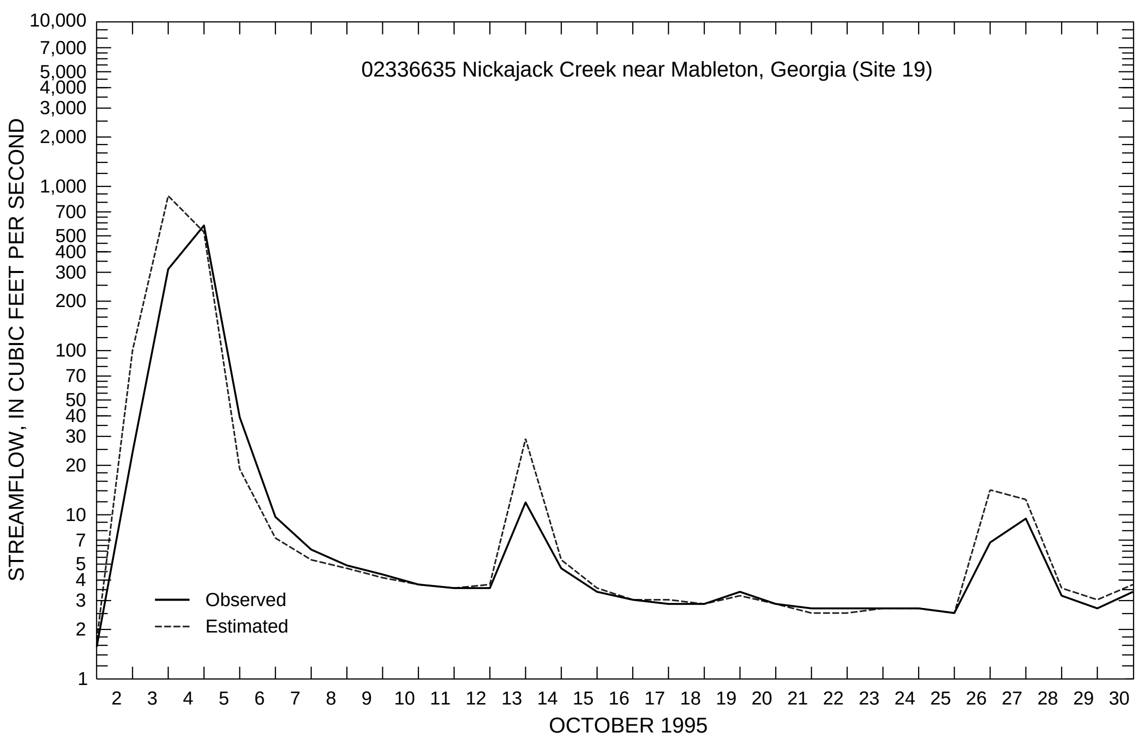

Figure 7. Comparison of observed and estimated daily tributary streamflow data for Nickajack Creek near Mableton, Georgia.

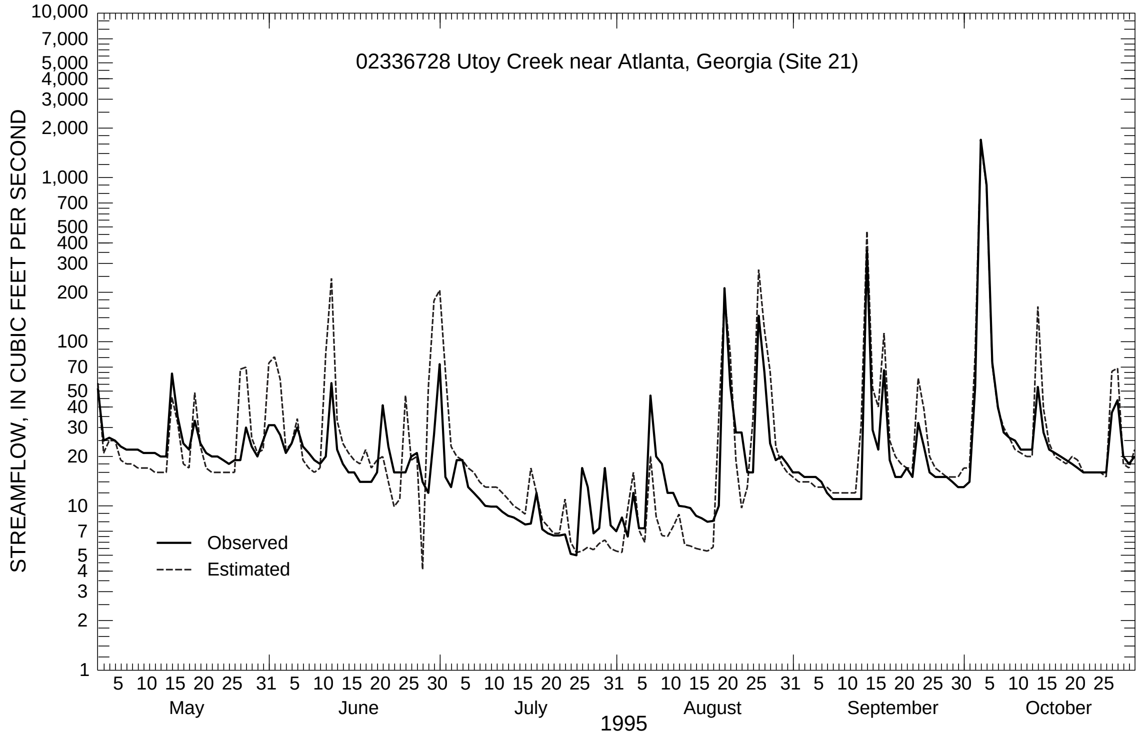

Figure 8. Comparison of observed and estimated daily tributary streamflow data for Utoy Creek near Atlanta, Georgia.

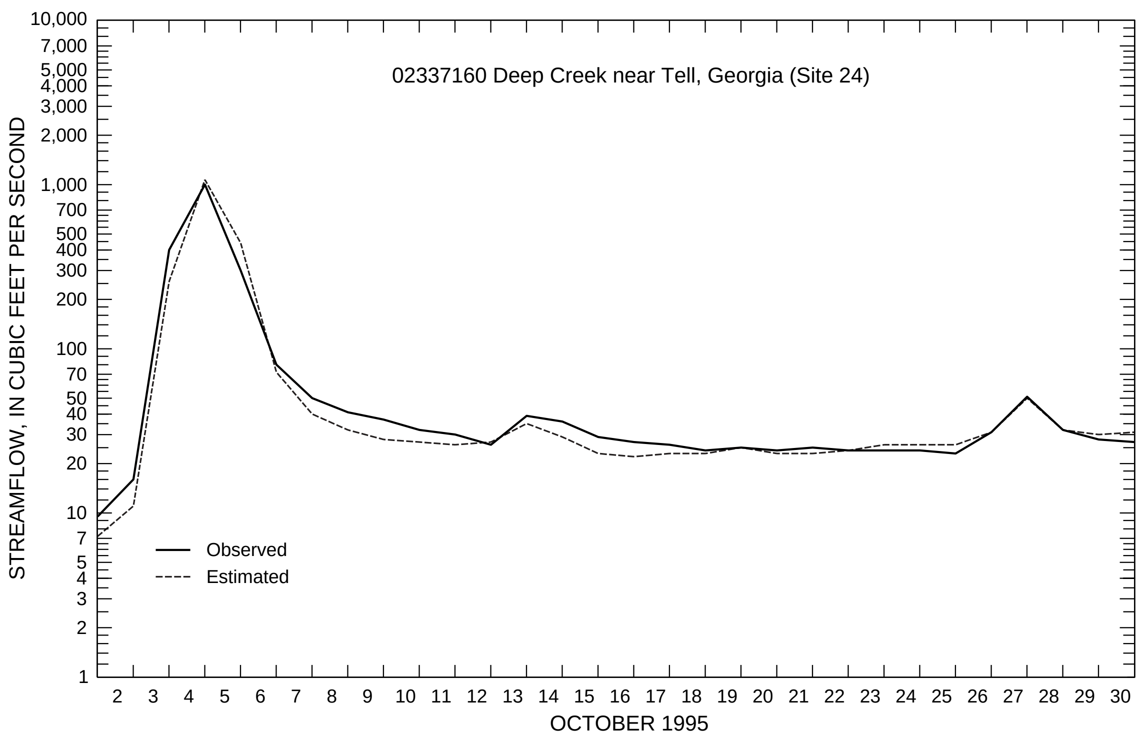

Figure 9. Comparison of observed and estimated daily tributary streamflow data for Deep Creek near Tell, Georgia.

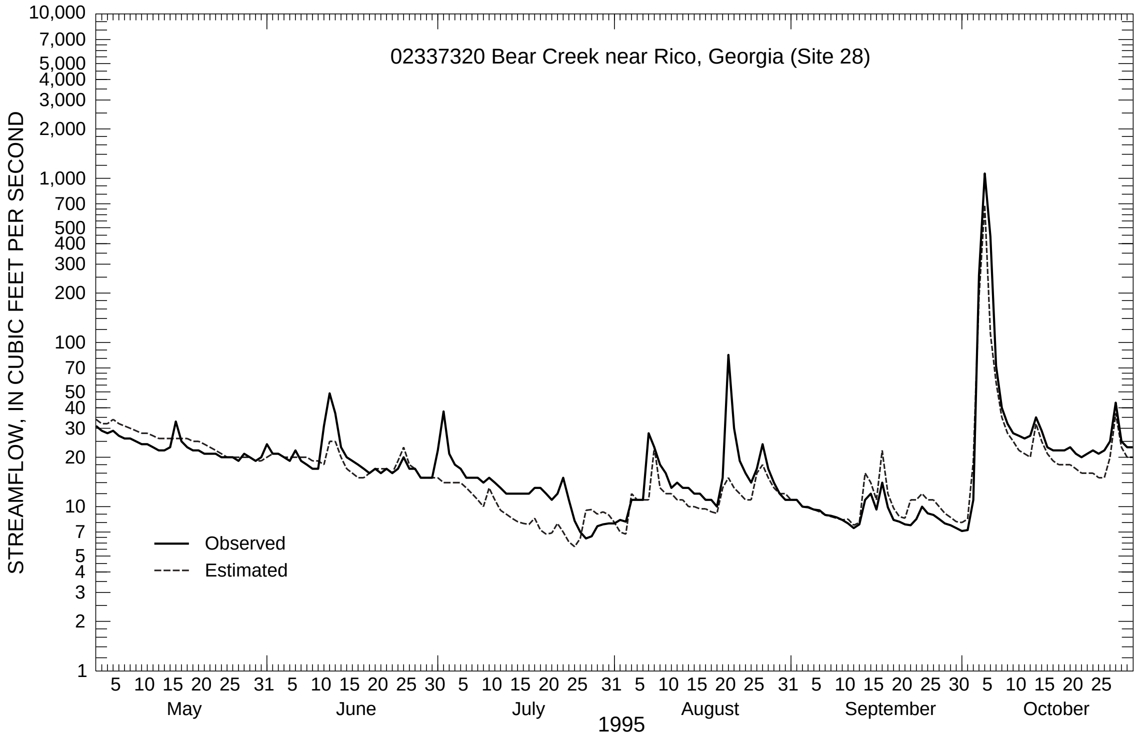

Figure 10. Comparison of observed and estimated daily tributary streamflow data for Bear Creek near Rico, Georgia.

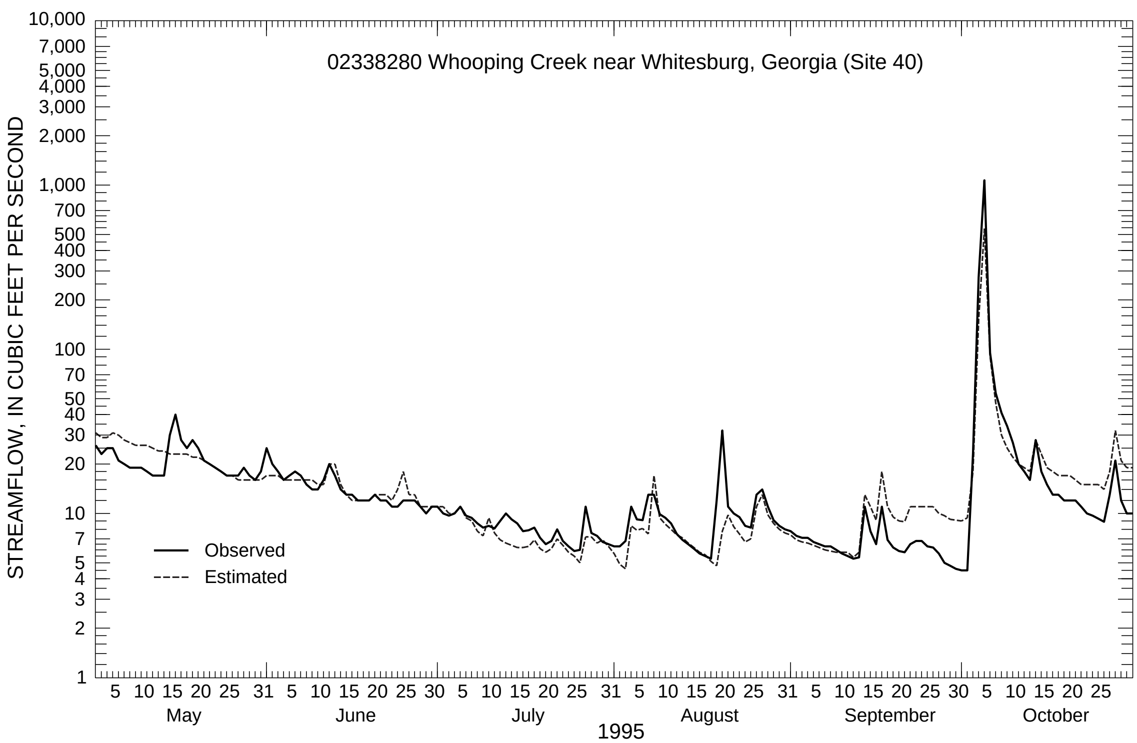

Figure 11. Comparison of observed and estimated daily tributary streamflow data for Whooping Creek near Whitesburg, Georgia.

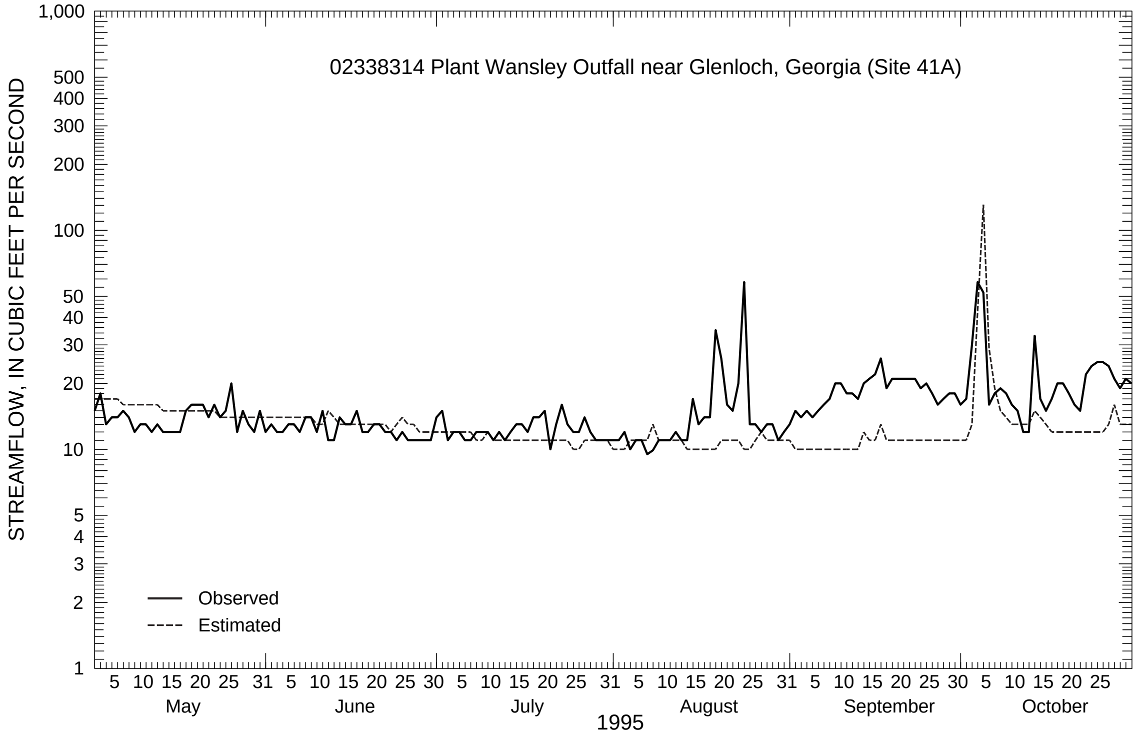

Figure 12. Comparison of observed and estimated daily tributary streamflow data for Plant Wansley Outfall near Glenloch, Georgia.

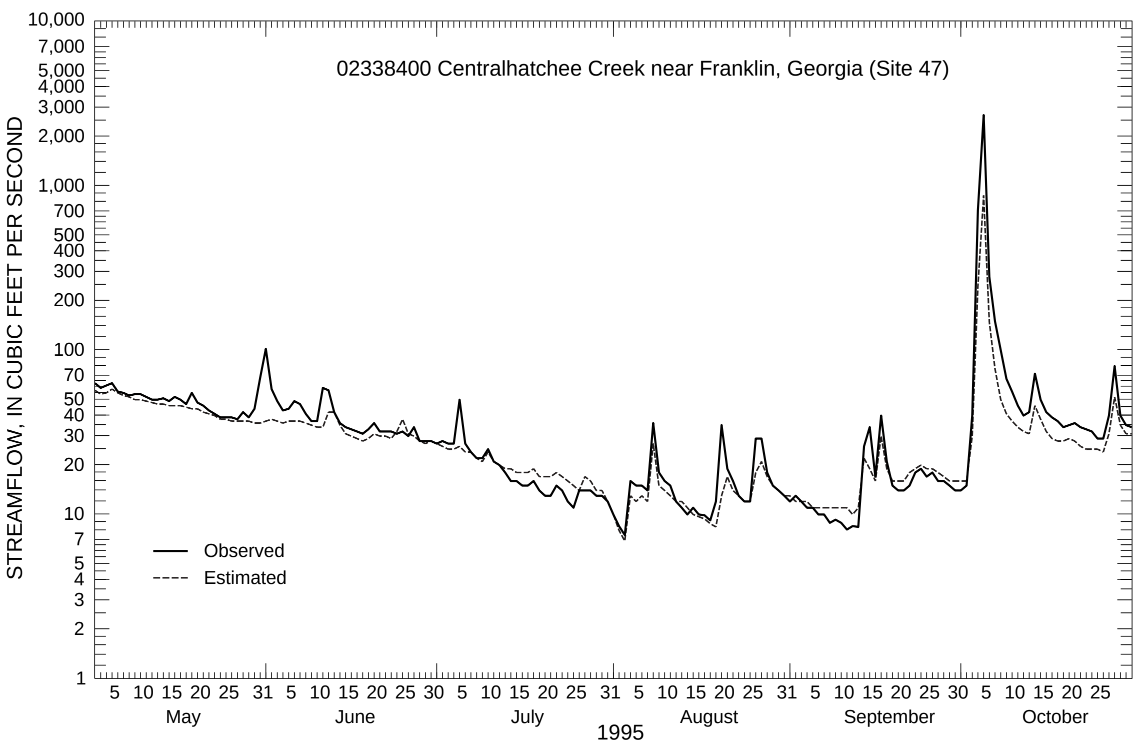

Figure 13. Comparison of observed and estimated daily tributary streamflow data for Centralhatchee Creek near Franklin, Georgia.

SUMMARY

Simple and reliable methods for estimating hourly streamflow are needed for the calibration and verification of the Chattahoochee River basin model from Buford Dam to Franklin, Ga. The model is being developed by Georgia Department of Natural Resources, Environmental Protection Division, as part of their Chattahoochee River Modeling Project. The streamflow data provided for the river basin model is only one component of the model which can allow water managers and regulators to make effective decisions within this part of the basin.

Streamflow data were collected for 47 Chattahoochee River tributaries (50 streamflow stations), with drainage areas greater than 3 mi^2 between Buford Dam and Franklin, Ga. The streamflow data were collected from April 1993 through October 1995 by the U.S. Geological Survey and the Georgia Environmental Protection Division. This report describes methods used in developing estimating equations for computing hourly and daily streamflow for the 47 tributary watersheds for input into the river basin model.

As of April 1994, there were only 6 continuous-record tributary streamflow stations in the study area. The tributary streamflow data collection network was expanded during 1994 and 1995 by establishing an additional 13 continuous-record streamflow stations. Concurrent streamflow data collected from the network of 19 continuous-record and 31 partial-record streamflow stations were used in ordinary least-squares linear regression analyses to define estimating equations and in verifying drainage-area prorations. The resulting regression or drainage-area ratio estimating equations were used to compute hourly streamflows at the partial-record stations. The coefficients of determination (r-squared values) for the computed regression estimating equations ranged from 0.90 to 0.99.

Because there are no other major inflows between the gaged locations and the tributary mouths, simple basin-adjustment factors using drainage-area prorations were developed and used to transfer streamflow data from the gaged locations to the mouth of the tributaries. Additional concurrent streamflow measurements also were made to confirm the applicability of the basin-adjustment factors.

Observed and estimated hourly and daily streamflow data were computed for May 1, 1995 through October 31, 1995, and furnished to the Georgia Department of Natural Resources, Environmental Protection Division, as part of their river basin model calibration and verification procedures. Comparisons of observed and estimated daily streamflow data made at 12 continuous-record tributary stations, which had available streamflow data for all or part of the period from May 1, 1995 to October 31, 1995, indicate that the mean error of estimate for the daily streamflows was about 25 percent.

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APPENDIX A—EXAMPLES OF DATA-ANALYSIS PROCEDURES

This section includes detailed descriptions and examples of procedures for the ordinary least-squares regression analysis, determination of drainage-area ratios, and determination of basin-adjustment factors that were used in this study.

Example of ordinary least-squares regression procedure: The regression procedure involves the collection and analysis of concurrent streamflows from the continuous-recording gages (index stations) and partial-record stations. The streamflow data are placed in a SAS data set and are regressed against each other using standard regression procedures (SAS Institute, Inc., 1990). Comparisons are made with several different continuous-recording gages and partial-record stations to determine the best correlated stations. The index stations that have the best correlations and that are generally in close proximity to partial-record stations are used in determining the streamflow estimating equations.

The data for 02337500 Snake Creek near Whitesburg, Ga (index station—site 34) and the partial-record station on Anneewakee Creek—site 25 (table 3), are listed in table A1.

The form of the estimating equation from the regression analysis (SAS Institute, Inc., 1990) is:

$$y = mx + b \qquad (1)$$

where

- y is the estimated streamflow at partial-record station (Anneewakee Creek—site 25), in cubic feet per second;
- m is regression coefficient (slope) determined from regression analysis;
- x is the streamflow at the index station in cubic feet per second (Snake Creek—site 34); and
- b is the regression constant (intercept) in cubic feet per second.

The estimating equation (table 3) computed for this set of data is:

$$y = .92 \text{ (Snake Creek—site 34)} - 1.9 \qquad (2)$$

A summary of streamflow measurements used in developing estimating equations for the remaining tributary stations using ordinary least-squares regression analyses is included in table A2. The range of measured streamflow can be compared with the applicable estimated data shown previously in figures 2-13. The number of streamflow measurements and the range in measured streamflow are included as additional information that may be later utilized in interpreting the overall accuracy of the estimating methods.

Example of procedure for determining drainage-area ratios**:** Drainage areas used in this study were determined by USGS and/or EPD from USGS topographic maps. To determine the drainage-area ratios (DAR) of the partial-record station, divide the drainage area for the partial-record station by the drainage area of the index station. The drainage area for James Creek—site 3, near Buford, Ga., is 15.2 mi^2 (partial-record station) and for 02335078 Johns Creek—site 7, near Alpharetta, Ga., (index station) is 11.6 mi^2. The computed DAR for James Creek is 1.31, as determined by dividing 15.2 by 11.6 (tables 1, 3). The hourly streamflow at the index station is multiplied by 1.31 (for this example), to compute corresponding estimated hourly streamflow at the partial-record station.

One of the two estimating methods, as described in the above two examples, was used in this study to determine the estimated hourly tributary streamflow at each of the partial-record stations. The computation procedure was accomplished by using the USGS data base processing programs in ADAPS (U.S. Geological Survey, 1990). The regression equations or DAR's were input into the data processing applications in ADAPS for the selected index stations and used to compute the hourly and daily streamflow for the corresponding partial-record stations (table 3).

Example of determining basin-adjustment factors**:** The final step in the data processing was to determine the streamflow at the confluence of each of the 47 selected tributaries to the Chattahoochee River. This was accomplished by computing a basin-adjustment factor (BAF). This is basically the same method as described in determining the above DAR example. The BAF is determined by taking tributary drainage area at the confluence with the Chattahoochee River and dividing it by the drainage area at tributary station were streamflow data were collected. For example: The drainage area for March Creek—site 13, is 5.3 mi^2 at the confluence with Chattahoochee River and is 4.8 mi^2 at data-collection point. The BAF is 1.10, as determined by dividing 5.3 by 4.8 (table 3). After the BAF's were determined and applied to the streamflow data for all 47 tributaries, the data were output and transferred to separate tab-delimited files to meet the EPD river basin model input format requirements.

Table A1. Concurrent streamflow data collected at Snake Creek—site 34, and Anneewakee Creek—site 25, near Whitesburg, Georgia, used in least-squares regression procedure
[ft^3/s, cubic feet per second]

Date	Streamflow	
	Snake Creek—site 34 (index station) (ft^3/s)	Anneewakee Creek—site 25 (partial-record station) (ft^3/s)
August 12,1993	22	17.4
September 1, 1993	14	9.6
September 22, 1993	14	14.9
October 19, 1993	13	11.2
November 4, 1993	17	14.6
May 9, 1994	37	32.0
May 23, 1994	28	22.5
June 7, 1994	29	21.5
June 21, 1994	19	14.0
July 20, 1994	64	56.8
August 17, 1994	78	76.9
August 31, 1994	38	29.1
September 15, 1994	32	26.9
September 29, 1994	35	32.3
October 17, 1994	58	55.4
May 22, 1995	43	24.5
June 6, 1995	37	29.6
June 20, 1995	31	20.6
July 5, 1995	26	29.1
July 19, 1995	16	10.0
August 2, 1995	11	10.5
August 16, 1995	12	9.0
August 30, 1995	15	18.1
September 28, 1995	16	16.5

Table A2. Summary of streamflow-measurement data used in the least-squares regression analyses
[ft^3/s, cubic feet per second]

Site number (fig. 1)	Stream name	Number of measurements used	Streamflow	
			Minimum measured (ft^3/s)	Maximum measured (ft^3/s)
2	Richland Creek	21	4.3	16.1
7	Johns Creek	10	1.4	10.3
9	Crooked Creek	15	1.3	9.7
12	Willeo Creek	27	1.0	35.2
16	Rottenwood Creek	17	4.6	26.2
17A	Nancy Creek	21	3.2	84.6
19	Nickajack Creek	19	7.9	45.0
20	Sandy Creek	26	0.3	10.1
21	Utoy Creek	37	6.6	332
25	Anneewakee Creek	24	9.0	76.9
29	Bear Creek	18	5.6	96.0
31	Hurricane Creek	7	2.6	9.3
32	Wolf Creek	27	4.3	51.3
35	Cedar Creek	23	2.9	126
35A	Panther Creek	13	0.9	6.9
36	Wahoo Creek	25	4.7	76.7
40	Whooping Creek	14	3.1	49.9
41A	Plant Wansley outfall	15	15.1	75.0
42	Pink Creek	6	1.0	18.0
43	Hilly Mill Creek	20	1.0	14.9
44	Red Bone Creek	7	0.1	5.2
45	Nutt Creek	7	0.1	8.6
46	Harris Creek	7	0.2	11.5
47	Centralhatchee Creek	10	7.0	101